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CORRELATION OF THE MIDDLE AND UPPER DEVONIAN AND THE MISSISSIPPIAN FAUNAS OF NORTH AMERICA¹

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V

INTRODUCTION.

NORTH AMERICAN DEVONIAN PROVINCES.

The Eastern Border Province.

The Eastern Continental Province.

Middle Devonian of the Eastern Continental Province.

Upper Devonian of the Eastern Continental Province.

The Interior Continental Province.

Middle and Upper Devonian of the Interior Continental Province.

Junction of the Eastern Continental and Interior Continental Provinces.

The Western Continental Province.

NORTH AMERICAN MISSISSIPPIAN PROVINCES.

The Mississippi Valley Basin.

The Southern Kinderhook Fauna.

The Northern Kinderhook Fauna.

Early Mississippian Faunas of the Appalachian Basin.

Post-Kinderhook Faunas of the Mississippi Valley Basin.

Mississippian Faunas of the Appalachian Basin.

Mississippian Faunas of the Rocky Mountain Basin.

Mississippian Faunas of the Western Continental Province.

INTRODUCTION

In its essential features a problem in geologic correlation is an investigation in the parallel histories of two or more regions, basins, or provinces, involving the points of contact between these areas. Since it is the fossil faunas which most satisfactorily indicate these points of contact, correlation problems, as applied to the stratified rocks of an age younger than the pre-Cambrian, are largely questions in paleontologic interpretation.

All questions in correlation become progressively more complex as the territory occupied by the faunas under consideration is extended.

¹ Read before Section E of the American Association for the Advancement of Science, Baltimore, Md., December, 1908.

So long as one's observations are restricted to a limited area contained entirely within a single life province, the problems are usually simple, and some beds with similar lithologic characters and similar faunules usually may be traced from section to section without abrupt changes. However, when one's observations extend beyond the limits of a single province or subprovince, the factors in correlation multiply, and frequently the problem becomes one of extreme complexity. In solving these problems the history of the faunas under consideration must be diligently studied in order to determine the elements in their composition, the source of these elements, and their relations one to another, both biologically, geographically, and geologically. The solution also involves the investigation of the paleogeography of the region being studied.

One of the first considerations in connection with any correlation problem is the determination of the several faunal provinces involved and their geographic limits.

NORTH AMERICAN DEVONIAN PROVINCES

Upon the North American continent four well-defined faunal provinces may be recognized in the Devonian strata. These have been designated by Williams:¹ (1) Eastern Border Province, (2) Eastern Continental Province, (3) Interior Continental Province, and (4) Western Continental Province. Although the boundary between the Eastern Continental and Interior Continental provinces is now known to be somewhat different from that assigned by Williams, the names themselves express better than any others which have been proposed the geographic relations of the provinces, and will be used here.

The Eastern Border Province is confined to the easternmost extremity of the continent, within the maritime provinces of Canada and the State of Maine. The outcropping strata of the Eastern Continental Province extend from eastern New York westward across New York and Ontario into Michigan, southwestward along the Appalachians across New Jersey, Pennsylvania, Maryland, West Virginia, and Virginia, also down the Ohio Valley through Ohio, Indiana, and Kentucky to southern Illinois, and southward into Tennessee, north-eastern Mississippi, Alabama, and Georgia. Outliers are found in

¹ *Am. Jour. Sci.* (3), XXXV, 51-59.

two regions which are at present wholly isolated from the main body of the province, (1) at Lake Memphremagog near the international boundary between Vermont and Quebec, and (2) southwest of James Bay in Canada. In both of these regions the faunas recognized are so like those of the Eastern Continental Province that there must have been direct communication to them during the life of the faunas.¹

The Interior Continental Province is typically developed in Iowa, where the Devonian strata are exposed from Muscatine County on the Mississippi River, northwestwardly across the state into the southern border of Minnesota, and it includes also the Devonian strata of Rock Island and Calhoun counties, Illinois, and those of Central Missouri. Beyond this the Devonian beds of Manitoba and the Mackenzie Valley are to be included in this same province, which seems to be connected in a northwesterly direction with the Eurasian Devonian Province. The Western Continental Province is confined to the Great Basin region, and its faunas are best known from the studies of Walcott² upon the Devonian faunas of the Eureka District in Nevada.

Since the faunas of the Eastern Continental Province have a more complete and continuous history than those of either of the other provinces, and because they are much better known, their succession is taken as the standard with which the other Devonian faunas of the continent are compared.

THE EASTERN BORDER PROVINCE

For substantial additions to our knowledge of the Devonian faunas of the Eastern Border Province we are recently indebted to Clarke,³ although contributions of great importance were made many years ago by the Canadian geologists, Logan and Billings. In this region the Helderbergian and Oriskany faunas of Lower Devonian age have a great development, and the faunas of the Gaspé basin give evidence that this region was a center of dispersion of these two faunas. During Middle Devonian time, in this same region, many of the Lower Devo-

¹ For composition of the Lake Memphremagog fauna see Ami, *Ann. Rep. Geol. Surv. Canada*, VII, N. S., 157J; also, Schuchert, *Am. Geol.*, XXXII, 155. For James Bay fauna see Parks, *Ont. Bureau Mines, Report for 1904*, Pt. I, pp. 180-91.

² *Monograph*, U. S. G. S., Vol. VIII.

³ "Early Devonian History of New York and Eastern North America," *Mem. N. Y. State Mus. Nat. Hist.*, Vol. IX.

nian types of life persisted to such an extent that the Gaspé sandstone has sometimes been correlated with the Oriskany of the Eastern Continental Province. It has been shown by Clarke, however, that associated with these Lower Devonian types there is a much more important element which allies the fauna with the Hamilton of the interior, the evidence being sufficient fully to justify the correlation of the Gaspé sandstone with the Middle Devonian. The Onondaga fauna is not differentiated in the Gaspé region.

The origin of the Hamilton fauna in the Gaspé basin is assumed by Clarke to have been by migration from the interior by way of the Connecticut and St. Lawrence troughs, and the presence of a similar fauna, showing a mingling of Oriskany and Hamilton types, on the island of St. Helen's near Montreal, gives some strength to such an assumption. However, the possibility of a southern origin, by way of the Atlantic border, should not be lost sight of.

THE EASTERN CONTINENTAL PROVINCE

Middle Devonian of the Eastern Continental Province.—In the Eastern Continental Province two major divisions of the Middle Devonian, the Onondaga and the Hamilton, are clearly recognized. These two faunas, with only minor, subprovincial differences, are persistent throughout the province, in New York, Ontario, Michigan, the Ohio Valley both east and west of the Cincinnati arch, in southern Illinois, and even in northeastern Mississippi and northern Alabama. The Onondaga fauna is in part an evolution product from the sub-jacent Oriskany, but, in addition, there are included in it at least three conspicuous elements which are entirely new, the corals, the cephalopods, and the fishes. This fauna has a greater distribution to the north than the superjacent Hamilton, it alone being represented in the outlying areas at Lake Memphremagog and James Bay. East of the Cincinnati arch, which was evidently a peninsula at this time, the Onondaga fauna does not extend far beyond the Ohio River, but west of this arch it is clearly recognized as far south as northeastern Mississippi. Throughout this entire area the composition of the fauna is wonderfully uniform.

The origin of the new elements in the Onondaga fauna is not entirely clear. It has been suggested by the writer¹ that these elements

¹ *Jour. Geol.*, X, 429.

have immigrated from the north by way of the tract now occupied by the fauna about James Bay, but there are few facts to support this hypothesis in the known distribution of the Devonian faunas of the Arctic region except the presence of several genera of fishes which occur in the fauna in America and in Devonian strata in Spitzbergen. The mingling of the Onondaga and Oriskany faunas in western Ontario, however, suggests that this was the first point of contact between the immigrant fauna and the pre-existing Oriskany, and would therefore indicate a northern origin for the fauna as a possibility. Ulrich and Schuchert¹ have postulated a southwestern origin, and later Schuchert² has suggested a northeastern origin for the fauna through the St. Lawrence Gulf and the Connecticut trough, but there seems to be as little basis for either of these hypotheses as for its northern origin.

East of the Cincinnati arch the Hamilton epoch is initiated by the fauna of the Marcellus shale which is evidently of Atlantic origin in so far as it is not evolved from the Onondaga, but this eastern incursion was of brief duration and did not penetrate to the subprovince lying west of the Cincinnati arch. The Hamilton proper is introduced throughout the province, both east and west of the Cincinnati arch, by the appearance in the faunas of certain peculiar brachiopods which are apparently of southern hemisphere origin, the most conspicuous of which are *Tropidoleptus carinatus* and *Chonetes coronatus*. Aside from this southern element the Hamilton fauna is in large part a derivative from the subjacent Onondaga, a considerable number of species being common to the Hamilton and the Onondaga, while many Hamilton species are closely allied, apparently genetically, to forms in the Onondaga fauna.

In its geographic distribution the Hamilton fauna does not extend as far north as the Onondaga, but it has a greater distribution southward along the Appalachians. West of the Cincinnati arch it is clearly defined in southern Illinois; it is probably present with the Onondaga in northeastern Mississippi, although data are not at hand to make a definite statement to that effect, and it has been clearly recognized in northern Alabama.³

¹ *Rep. N. Y. State Pal.*, 1901, p. 652.

³ Schuchert, *Am. Geol.*, XXXII, 152.

² *Am. Geol.*, XXXII, 156.

During the Hamilton period the sea retreated from the northern embayments in the James Bay region and the Connecticut trough, and at the same time it transgressed toward the south and occupied territory which had been dry land during Onondaga time, and connection was apparently established between the eastern and western sub-provinces to the south of the Cincinnati arch, which at this time became an island.

Upper Devonian of the Eastern Continental Province.—During Upper Devonian time the faunas of the Eastern Continental Province were far more local in their development than they had been at any time during the Middle Devonian. At no time during the period was there so uniform a fauna as either the Onondaga or the Hamilton had been, distributed throughout the entire province. In the early Upper Devonian time the sea retreated northward from its greatest southward extension of Hamilton time, and later again transgressed toward the south and southwest until it extended much farther than it had in the earlier period, this retreat and readvance being recorded in the unconformity at the base of the Upper Devonian black shale which is commonly exhibited south of the Ohio River and to some extent north of that stream.¹

The earliest Upper Devonian fauna in the province is the Cuboides fauna of the Tully limestone in New York, characterized by a totally new immigrant element in the Devonian faunas of the province, of which the brachiopod species *Hypothyris cuboides* is the most conspicuous representative. This fauna has been shown by Williams² to be closely allied to the Cuboides fauna of the European Devonian which initiates the Upper Devonian of that continent. The Cuboides fauna in America must have had a common origin with the same fauna in Europe, and the path of its immigration into the Eastern Continental Province of North America is commonly considered to have been by way of the Interior Continental Province.

Following the Tully limestone in the northeastern portion of the province is the Genesee black shale with a meager fauna of which the Lingulas are the most conspicuous members. In the southern portion

¹ Data concerning this unconformity have been assembled by Foerste, *Ky. Geol. Surv., Bull. No. 7*, p. 129.

² *Bull. G. S. A.*, I, 481-500.

of the province the entire Upper Devonian epoch is represented by a black shale which has been variously called the Ohio shale, the New Albany shale, or the Chattanooga shale, which is widely distributed in southern Ohio, Indiana, and Illinois, in Kentucky, Tennessee, and northern Mississippi, Alabama, and Georgia, and extends westward into northern Arkansas. Throughout the southern portion of the province this black shale rests unconformably upon the subjacent strata, and in some parts of Kentucky, at least, is unconformable upon Middle Devonian limestones. In the Ohio Valley the fauna in the basal portion of the black shale indicates its Genesee age,¹ but as the shale was a transgressing formation toward the south and southwest, its age in these directions becomes younger and younger, and at the extreme limits of its extension it may even be younger than any true Devonian, and be contemporaneous with the basal member of the Mississippian.

While these monotonous black shale conditions obtained in the south, a series of waves of faunal immigration were penetrating the northeastern portion of the province. In the Portage of western New York occurs the *Intumescens* fauna² characterized by its numerous goniatites of the type of *Manticoceras intumescens*. This fauna, like the *Cuboides* fauna of the Tully limestone, is of European origin. The path of its migration into New York is believed by Clarke to have been the same as that of the earlier fauna, by way of the Interior Continental Province, but Ulrich and Schuchert³ express the opinion that it came in from the Atlantic basin by an eastern route. Following the *Intumescens* fauna, in the same general region, is a fauna in the High Point sandstone, at the extreme summit of the Portage group, characterized by *Pugnax* of the type of *P. pugnus*, which is another European immigrant, and which has many species in common with the Lime Creek shales of the Interior Continental Province in Iowa. Succeeding the High Point fauna is the typical Chemung fauna with *Spirifer disjunctus* and its associates, which again are European immigrants, but are associated with other forms which are of Hamilton derivation.

¹ For a summation of the opinions which have been held in regard to the age of the black shale, see Girty, *Am. Jour. Sci.* (3), VI, 385, 386.

² Clarke, "The Naples Fauna in Western New York," *Sixteenth Ann. Rep. New York State Geol.*, 1896, pp. 31-161; also *Mem. N. Y. State Mus.*, No. 6.

³ *Loc. cit.*

In central New York the history is somewhat different in that the *Intumescens* fauna does not penetrate there in its typical expression, and the Ithaca beds, which are equivalent to the Portage, carry a fauna which is in large part a Hamilton derivative, this being followed by the Chemung fauna. Still farther east, in the same state, the Portage epoch is represented by the non-marine Oneonta sandstone which is followed by marine beds with a recurrent fauna, which pass upward into the Chemung. In the extreme eastern portion of New York the non-marine Catskill conditions were doubtless constant from the beginning of the Upper Devonian until its close.

THE INTERIOR CONTINENTAL PROVINCE

Middle and Upper Devonian of the Interior Continental Province.—

In passing from the Eastern Continental to the Interior Continental provinces, both the stratigraphic and faunal conditions are found to be totally different in almost every detail. In New York, where the Middle and Upper Devonian beds of the Eastern Continental Province have their most typical development, a maximum thickness of more than 3,000 feet of strata is recognized, and in the Appalachians in Pennsylvania the thickness is much greater, but in Iowa the total thickness of the Devonian beds of the Interior Continental Province is less than 300 feet. The entire series of Devonian beds in Iowa are commonly referred to the Middle and Upper Devonian, the Upper beds being unconformable upon the Middle,¹ but the limits of these divisions do not correspond at all with the limits of the Middle and Upper divisions of the Devonian in the Eastern Continental Province.

In the Middle Devonian of the Iowa geologists two major divisions are recognized, the Wapsipinicon and the Cedar Valley. Both the Wapsipinicon and the Cedar Valley are made up of minor formational units of more or less local development, and of these the Independence shales occupy a position near the base of the Wapsipinicon. The fauna of the Independence shales is the oldest of the Devonian faunas of Iowa,² and it shows much in common with the fauna of the Lime Creek shale of the Upper Devonian of the same state.

In the Upper Devonian three formations are included in Iowa, the Lime Creek shales, the State Quarry beds, and the Sweetland Creek

¹ Calvin, *Jour. Geol.*, XIV, 575; also *Ia. Geol. Surv.*, XVII, 197.

² Calvin, *Bull. U. S. Geol. Surv. Terr.*, IV, 725.

shale. As regards the relations of these three formations Calvin says:¹ "The three units referred to the Upper Devonian—the Sweetland Creek shales, Lime Creek shales, and State Quarry limestone—do not lie one above the other, but each is locally developed and lies unconformably on the Cedar Valley limestones."

The lower beds of the Wapsipinicon stage, other than the Independence shale, do not furnish any considerable fauna, *Martinia subumbona* being the most conspicuous species, but the higher beds, as well as the succeeding Cedar Valley beds, are abundantly fossiliferous, and faunally the dividing-line between the Wapsipinicon and Cedar Valley stages presents no more conspicuous break than that between the successive beds included within the Cedar Valley.

In correlating these faunas of the Iowan Devonian with those of the Eastern Continental Province, difficulty is met with because of the few points of contact between the two faunas. The faunas in the two provinces are so distinctly different that we are forced to the conclusion that there could have been no free communication between the two regions, but that they must have been entirely separated during the whole or the greater part of Middle Devonian time by some barrier, probably a land mass. During Upper Devonian time there was much more in common between the Iowan and New York faunas, showing that communication had been established ere that time. In the correlation of the faunas in the two provinces the important point to determine is the time of the establishment of this communication. Williams² has shown that the *Cuboides* fauna of the Tully limestone in New York is a distinct immigrant fauna from the Eurasian province, probably by way of the Mackenzie Valley and Iowa. The characteristic species of this fauna is *Hypothyris cuboides*, a species which is represented in the Iowan faunas by *Rhynchonella intermedia* Barris, the Iowan form apparently being specifically identical with the New York species. In Iowa this species is limited in its range to the upper portion of the Wapsipinicon stage, where it is highly characteristic of one of the divisions of the Fayette breccia,³ and where it is associated with *Gypidula comis*. Because of the limited range of this species in

¹ *Jour. Geol.*, XIV, 575; also *Ia. Geol. Surv.*, XVII, 197.

² *Bull. G. S. A.*, I, 481-500.

³ Norton, *Iowa Geol. Rep.*, IV, 160.

these Iowan beds, it seems safe to conclude that these higher Wapsipinicon beds are essentially equivalent in time with the Tully limestone of New York. Furthermore, almost the only fossil species in the lower Wapsipinicon beds is *Martinia subumbona*, which also is a common Tully limestone species.

Another point of contact between the faunas of the Iowan and the New York provinces is found in the faunas of the Lime Creek shales of Iowa and the High Point sandstone near Naples, N. Y. The High Point bed lies at the extreme top of the Portage in the New York section, and in a total fauna of 26 species, 14 are also present in the Lime Creek beds of Iowa.¹ This large proportion of identical species may be considered as a sufficient basis for the essential correlation of the beds.

If these two correlations are correct, a basis is established for the correlation of the entire Devonian series of Iowa, the Wapsipinicon being, in the main, the time equivalent of the later Hamilton of the New York section, its termination being essentially contemporaneous with the Tully limestone, the Cedar Valley being contemporaneous with the Portage group of New York, and the Lime Creek being contemporaneous with the closing stages of the Portage and the opening of the Chemung. There is no evidence whatever of the presence of any beds of Onondaga age in Iowa.

The invertebrate faunas of the so-called Upper Devonian formations of Iowa are less prolific than those of the Cedar Valley beds. The Lime Creek fauna includes a number of forms which are recurrent from the Independence shales near the base of the Wapsipinicon, a distribution which suggests the unity of the entire Devonian fauna of Iowa, and, further, that the Lime Creek is not far removed from the subjacent beds although there is apparently an unconformity between them. The State Quarry beds contain a number of distinctly Devonian brachiopods, among which may be mentioned *Pugnax alta* which also occurs in the Lime Creek shales, but the most conspicuous feature consists of the fish remains, *Ptyctodus calceolus* being the most abundant form. In the Sweetland Creek shales invertebrates are few in number, a species of *Spathiocaris* being perhaps the most common, a species which also occurs in the New Albany black shale of southern

¹ Clarke, *Bull. U. S. G. S.*, No. 16, p. 75.

Illinois and Indiana, as well as in a basal Kinderhook shale in Missouri. At the base of the formation a thin band occurs which is frequently crowded with the teeth of *Ptyctodus calceolus*, the same species which is present in the State Quarry beds and one which also has a wide distribution at the very base of the Kinderhook formations.

Following the Devonian of the Interior Continental Province to the northwest, it is next well exposed in Manitoba, and has been well described by Tyrrell.¹ Approximately 510 feet of strata are recognized, the lower 100 feet not having afforded any fauna. The beds referred to the Middle Devonian (Winnipegosis) are characterized by the presence of *Gypidula comis* throughout, and by *Stringocephalus burtoni* in the upper portion. The last of these species does not occur in Iowa, but *Gypidula comis* is an abundant and characteristic member of the fauna of the upper beds of the Wapsipinicon stage, where it is associated with *Rhynchonella intermedia* Barris (*Hypothyris cuboides*). In western Europe *Stringocephalus burtoni* is the index fossil of the Stringocephalus limestone at the summit of the Middle Devonian, and occurs immediately beneath the Cuboides zone. The Devonian beds superjacent to the Stringocephalus beds in Manitoba have been referred to the Upper Devonian by the Canadian geologists, a correlation which is doubtless correct, since the faunal succession is similar to that in Europe, where *Stringocephalus burtoni* marks a distinct horizon at the summit of the Middle Devonian.

The Devonian fauna of the Mackenzie basin has been described by Whiteaves² and has been correlated with the Cuboides zone of Europe and New York, a correlation which seems to be based on substantial evidence. Seventy-six forms are specifically identified, twenty-nine of which are either present or are represented by close relatives in the European faunas of similar age, while twenty-two are identified with American Hamilton species, ten with Iowan and seven with Chemung forms. In the Mackenzie basin the Stringocephalus zone has not been so clearly recognized as in Manitoba, although it is indicated in at least one locality. The entire Devonian section in the Mackenzie Basin consists of 2,800 feet of strata, but a considerable part of the lower portion may be of greater age, and the entire fauna is

¹ *Geol. Surv. Canada, Ann. Rep.*, V, (N. S.), Pt. I, pp. 204-9 E.

² *Cont. Can. Pal.*, I, 197-253, pls. 27-32.

known from 200 feet of beds between 300 and 500 feet below the summit of the entire series.

JUNCTION OF THE EASTERN CONTINENTAL AND INTERIOR CONTINENTAL PROVINCES

As has been indicated in the previous discussion of the faunas of the Eastern Continental and Interior Continental Provinces, the time of the establishment of a path of communication between the two was at the very opening of the Upper Devonian, when the Cuboides fauna found its way into the East, but the relations of the Iowan faunas with those of the East is not such as to suggest an entirely unobstructed intermingling of faunas even after this communication was finally established. Schuchert has suggested in his paleogeographic maps¹ that this communication was by way of a narrow and somewhat tortuous strait, the "Traverse Strait," which passed from southeastern Iowa in a general northeasterly direction, across Illinois through the Lake Michigan basin to northern Michigan. Within the limits of this strait occur the Devonian beds near Milwaukee, Wis., and those of the Grand Traverse region of Michigan, where there is a greater comingling of eastern and western forms than elsewhere, as might be expected under the circumstances. The waters of this strait were separated from those of the Eastern Continental basin by the comparatively narrow Kankakee peninsula.

THE WESTERN CONTINENTAL PROVINCE

The Devonian strata of the Western Continental Province occur at various localities in the Great Basin region, and their faunas have been described by Walcott in his *Paleontology of the Eureka District*.² One hundred and eighty specifically identified forms are recorded, of which 61 are new and 119 are identified with already known forms. The composition of the previously known portion of the fauna is as follows: 83 species are identical with forms from the Eastern Continental Province, including New York, Michigan, and the Ohio Valley, the other 36 being known from Iowa and other parts of the Interior Continental Province. Of the eastern species 29 are found only in the Onondaga fauna, 21 only in the Hamilton, and 13 only in Devonian

¹ *Am. Geol.*, XXXII, Pl. 21; also, *Ia. Geol. Surv.*, XVIII, pl. 16.

² *Monograph*, U. S. G. S., Vol. VIII.

beds younger than the Hamilton; the remaining species are common to the Onondaga and the Hamilton, with one exception, which occurs in the Hamilton and the Chemung. From these figures it is evident that this Great Basin fauna contains a strong Onondaga element, 48 species in all. Of the Hamilton species neither *Tropidoleptus carinatus*,¹ *Chonetes coronatus*, nor any of the strictly foreign species in the fauna are recognized, the entire Hamilton element being of that association which seems to have originated from the Onondaga. Of the three highly characteristic elements of the Onondaga fauna of the East, corals, cephalopods, and fishes, we find 11 species of corals and 11 species of cephalopods, but none of the latter are identical with those of the East, although they are congeneric. Of ichthyic remains but a single tooth was collected by Walcott, but in the Kanab Cañon of northern Arizona a strongly marked Devonian fish horizon is recorded,² although the composition of the fauna has not been made known.

In its entirety the Devonian fauna of the Western Continental Province may be said to be composed of a combination of two distinct elements: (1) the Middle Devonian fauna of the Eastern Continental Province, exclusive of the southern hemisphere element in the Hamilton, and (2) the fauna of the Interior Continental Province. These two elements are not fully differentiated in the faunas, since species from the Iowan or Mackenzie Basin faunas occur indiscriminately in either the lower, middle or upper divisions of the Great Basin Devonian. The Onondaga element also occurs through all of the divisions, although it is most conspicuous in the lower beds. Within this province there is no faunal evidence indicating the presence of Devonian rocks of greater age than the Onondaga, but sediments were doubtless deposited in the area contemporaneously with the Onondaga, Hamilton, and Upper Devonian of the Eastern Continental Province, but no beds can be correlated definitely with either of the eastern formations. The older of the beds are doubtless of greater age than the oldest Devonian beds of Iowa, although they may not be older than some of those of the Mackenzie Valley.

¹ *Tropidoleptus carinatus* has been recorded from the Pinon Range, Nevada, but the species has not been figured, and the identification has not been confirmed, *Monograph*, U. S. G. S., VIII, 276.

² Walcott, *Monograph*, U. S. G. S., VIII, 7; also *Am. Jour. Sci.* (3), XX, 225.

The path of communication between the Eastern Continental Province, in Onondaga time, and the Western Continental Province must have been indirect, although there was certainly some community of origin of the faunas in the two regions. If the northern origin of the Onondaga fauna, as has been suggested by the writer,¹ has sufficient foundation, which is perhaps doubtful, the fauna may have migrated southward into two epicontinental embayments, one into the Eastern Continental Province, by way of Hudson Bay and James Bay, and another farther west into the Western Continental Province. The mingling of the Onondaga and the Iowan faunas might be accounted for on this basis, since it is quite definitely recognized that the latter fauna has a northwestern origin, at least in so far as North America is concerned. One objection to this view is the fact that the Onondaga fauna is not represented among the known faunas from the Mackenzie Basin, although there is sufficient room for its occurrence in some of the older Devonian beds of that region which have not yet afforded any fauna. A southern pathway of communication between the two provinces is a possibility, although on such an hypothesis the absence of the southern hemisphere element of the later Middle Devonian faunas of the East is not easy to account for.

THE NORTH AMERICAN MISSISSIPPIAN PROVINCES

The early stages of the Mississippian period were marked by a continuation of the transgression of the sea in the south and southwestern part of the Eastern Continental Province, which had been initiated during Upper Devonian time, but it was extended also to the northwest. Before the close of the Kinderhook epoch, the sea had crossed the Kankakee peninsula and had surrounded the Ozark land which became an island or was perhaps entirely submerged, and had stretched away toward the Rocky Mountain land, so that the earlier Eastern Continental and Interior Continental provinces were merged into one great interior province with three subordinate basins or subprovinces, (1) the Appalachian Basin lying between Appalachia and the Cincinnati arch and extending from Michigan to Alabama, (2) the Mississippi Valley basin extending westward from the Cincinnati arch and merging with the Appalachian Basin to the south, (3)

¹ *Jour. Geol.*, X, 429.

the Rocky Mountain Basin. The Western Continental Province remained much as in Devonian time, faunally isolated to a great extent from the interior province. The Eastern Border Province was even more isolated, its faunal history, so far as known, having no points of contact with the interior.

The more complete and differentiated faunal history of the Mississippian is that of the Mississippi Valley Basin which will be used as a standard of comparison for the other provinces or subprovinces considered.

THE MISSISSIPPI VALLEY BASIN

The Southern Kinderhook fauna.—When the Upper Devonian or New Albany black shale is well developed in southern Indiana and Illinois, the initial Kinderhook bed, the Rockford limestone, follows it with no stratigraphic break. In following the Kinderhook beds to the north, however, they are found to succeed, unconformably, formations of much greater age. The same condition also probably holds in passing from Burlington, Ia., to the south, although the transition beds from the Devonian to the Kinderhook are not exposed in the Burlington section. An actual land barrier, the Kankakee axis of Schuchert, separated these northern and southern basins at the beginning of Kinderhook time, when each basin was occupied by its own distinctive and characteristic fauna. Before the close of the Kinderhook this barrier was submerged and a common fauna occupied the entire Mississippi Valley Basin.

The fauna of the Rockford limestone contains new elements which were unknown in the preceding Devonian faunas, associated with certain other forms which are clearly Devonian derivatives. The typical expression of this more southern type of the Kinderhook fauna, however, is found in the Chouteau limestone of central and southern Missouri and Illinois, although there are several modifications of the fauna in the various more or less local formational units of the Kinderhook of this region. Among other things the fauna contains numerous goniatites, some of which are notable forms and have no relationships with any of our known Devonian goniatites. *Aganides rotatorius*, from the Rockford goniatite bed of Indiana, is identical with a form in the basal Mississippian beds of Belgium and Ireland. Associated

with this form at Rockford is *Prodromites gorbyi* which occurs also in the Chouteau limestone of central Missouri. This latter goniatite is the most advanced one of the Mississippian faunas, having, as it does, a secondarily lobed suture such as, at no very distant period in the past, was considered to be characteristically Mesozoic in type. Another peculiar cephalopod in the fauna is *Tribloceras digonum* which occurs in the fauna at various localities. A peculiar type of pelecypod is found in the genus *Promacrus*, which occurs also in the early Mississippian beds of Belgium. These and many other forms in the fauna characterize it as something distinctly younger than any Devonian fauna, with numerous bonds of affinity uniting it with the higher and more typical Mississippian faunas. However, there occur associated with these characteristic portions of the fauna certain species, especially among the pelecypods, which are clearly Devonian derivatives, and, strange to say, their relationships are usually with members of the Hamilton fauna, rather than with the higher Devonian faunas of the Eastern Continental Province. The Hamilton relationships of the fauna are perhaps best seen in the fauna of the Glen Park limestone,¹ where the pelecypods and gastropods are all close allies of Hamilton forms, and where one form even seems to be specifically identical, but associated with these is a member of the highly characteristic Mississippian genus *Syringothyris*.²

The origin of this southern Kinderhook or Chouteau fauna is believed to have been in the Atlantic Basin, where Middle Devonian faunas of Hamilton type had probably retreated as the Upper Devonian immigrants became established in the Eastern Continental Province, or where they had persisted during Upper Devonian time, having never been encroached upon by the immigrants. During the long lapse of time most of the species had been modified, and there had been absorbed into the fauna a new element from some unknown region. The return of this fauna into the Mississippi Valley Basin marks the opening of the Kinderhook epoch and the Mississippian period.

¹ Weller, *Trans. St. Louis Acad. Sci.*, XVI, 435-71.

² The species described in the *Fauna of the Glen Park Limestone* (*loc. cit.*) as *Spirifer jeffersonensis*, has since been definitely identified as a member of the genus *Syringothyris*.

The Northern Kinderhook fauna.—North and west of the Kankakee peninsula, in the eastern portion of the Devonian Interior Continental Province, the earliest Mississippian faunas were as distinctly different from those of the southern portion of the Eastern Continental Province, as had been the preceding Devonian faunas. The oldest of these northern Kinderhook faunas is that of the *Chonopectus* sandstone¹ at Burlington, Ia., and elsewhere in Iowa and Illinois. This fauna contains a large Devonian derivative element, especially among the pelecypods, but its relationships are with the Chemung faunas of the Upper Devonian, and are totally different from the Devonian derivatives of the southern fauna. Another modification of the northern Kinderhook fauna is found in the Louisiana limestone, which is believed to be in part contemporaneous with, and in part younger than, the *Chonopectus* fauna. One of the most characteristic members of this northern Kinderhook fauna is the striated rhynchonelloid genus *Paraphorhynchus* which occurs also in the early Mississippian faunas of northwestern Pennsylvania.

In the Burlington, Ia., section the *Chonopectus* fauna occurs at the summit of a series of shales, becoming arenaceous above where the fauna occurs, which have a total depth of 160 feet. The lower 100 feet of the formation lies beneath the level of the Mississippi River, so that the contact with the underlying formation and the age of the subjacent bed is not known. This lower bed, however, is probably Devonian, and is not unlikely the Cedar Valley limestone, since that formation lies unconformably beneath the Kinderhook beds farther south in Calhoun County, Ill. If this is the case then these lower shales of the Kinderhook correspond in position with the Sweetland Creek shales of the Upper Devonian in Muscatine County, Ia. There is, however, perhaps insufficient faunal evidence upon which to base a definite correlation of these two shale formations. The most conspicuous faunal character of the Sweetland Creek beds is the presence of numerous *Ptyctodus* teeth in the basal bed, occupying a few inches above the unconformity. A similar *Ptyctodus* bed occurs not infrequently at the base of the Kinderhook in both the northern and southern provinces. Such is the case at the base of the Louisiana limestone at Louisiana, Mo., where *Ptyctodus* occurs abundantly in a thin shale

¹ Weller, *Trans. St. Louis Acad. Sci.*, X, 57-129; also *Jour. Geol.*, XIII, 617-34.

bed beneath the limestone. In southeastern Missouri a one-foot bed of sandstone occurs at the base of the Kinderhook with numerous phosphatic nodules and some worn *Ptyctodus* teeth. In southwestern Missouri a thin formation at the base of the Kinderhook has been described by Shepard¹ as the Phelps sandstone, in which *Ptyctodus* teeth are abundant, and the same conditions obtain at Providence,² in central Missouri. In all of these localities the same species, *Ptyctodus calceolus* N. and W., seems to be the usual form. Occupying, as these *Ptyctodus* beds do, a position immediately superjacent to a more or less profound unconformity, it is not likely that it is strictly contemporaneous in all of these localities, but that they are all associated with one general geologic movement, and are contemporaneous within comparatively narrow limits, is quite certain. The presence of the remains of this fish fauna, in both the southern and northern Kinderhook provinces, while the invertebrate faunas are so distinct, is doubtless due to the fact of the greater mobility of the fishes, and their greater powers of adaptation to certain changing conditions. Besides these fish remains, the most common fossil in the Sweetland Creek beds is a crustacean belonging to the genus *Spathiocaris*, which also occurs in the Upper Devonian black shale in southern Indiana and Illinois, and in a basal Kinderhook shale in southwestern Missouri. This crustacean, like some of the Lingulas, seems to be associated rather with a peculiar type of sediment than with a definite time period of narrow limits. Neither the *Ptyctodus* nor the *Spathiocaris* have been found in the basal Kinderhook shales at Burlington, but the fauna of the basal portion of the formation is of course not known.

During the progress of Kinderhook time the sea was encroaching from both the north and the south, until before the close of the epoch free communication was established between the earlier separated provinces and the fauna of the southern province became the dominant type throughout the entire Mississippi Valley Basin. This northern incursion of the southern fauna is well exhibited in the uppermost 15 feet of the Kinderhook section at Burlington and elsewhere.

From the outline of the faunal history here given, it is evident that the arrangement of the Kinderhook formations into three successive

¹ *Mo. Geol. Surv.*, XII, 77.

² "Bed No. 4, Stewart," *Kansas Univ. Quart.*, IV, 161.

divisions, the Louisiana, Hannibal, and Chouteau, as has usually been done, does not express the proper relationships of the faunas. The Chouteau fauna, in some of its expressions, is without doubt as old as the Louisiana fauna, and it is as impracticable to make one continuous section to contain all of the Kinderhook formations, as it would be to make a standard Devonian section to include the formations of New York and Iowa.

Early Mississippian faunas of the Appalachian Basin.—In the waters between the Cincinnati arch and the old Appalachian land in early Mississippian time, the faunal conditions were more like those of the southern Kinderhook province than the northern. In the Bedford shale of that basin a fauna occurs which is largely of Devonian derived species, and like the southern Kinderhook faunas these species have their relationships with Hamilton rather than with Upper Devonian forms. The succeeding formations in Ohio constitute the several members of the Waverly group with faunas showing more or less close relations with those of the southern Kinderhook. In the northern part of the basin, as in the Waverly beds of northwestern Pennsylvania, the presence of such forms as *Paraphorhynchus*¹ suggest relationships with the northern Kinderhook faunas of the Mississippi Valley, a relationship which might have been established by faunal migration from the West to the East by way of the Traverse Strait and Michigan.

Post-Kinderhook faunas of the Mississippi Valley Basin.—With the submergence of the Kankakee Peninsula and the partial or complete submergence of the Ozark land, the source of the clastic sediments in the immediate Mississippi Valley region was removed, and a great period of limestone formation was initiated which is best exemplified in the Burlington and Keokuk formations. The fauna of this clear sea was in large part an outgrowth of the later Kinderhook faunas, and is best characterized by the wonderfully rich crinoidal element.

The fauna of the formations which together constitute the Osage division of the Mississippian is in some respects unique. The great crinoidal element is in large part or wholly indigenous to this province,

¹ *Rhynchonella medialis* and *R. striata* Simpson (*Trans. Am. Phil. Soc.*, XV, 144), from Warren County, Pa., are members of this genus.

although it had its beginnings in the preceding Kinderhook. No locality in the world, so far as known, has furnished so large a number of crinoids of similar age, either in genera, species, or individuals, as this Mississippian province. The fauna, in its entirety, exhibits much in common with the mountain limestone of England, Ireland, and elsewhere in Europe. Many species of brachiopods in the formations either are identical or are so closely allied as to be difficult of separation, and the correlation of the Osage with the Mountain Limestone of England, or at least of some part of it, is based upon substantial evidence. Evidence sustaining the indigenous character of the crinoidal element in the fauna is found in a comparison of these forms from the Osage of the Mississippi Basin and from the Mountain Limestone of Europe. Every genus in the Mountain Limestone occurs also in the American faunas, while there are many genera which do not occur outside of the Mississippi Basin; furthermore, all of those genera which occur in both this Mississippian province and in Europe are represented by a larger number of species in America. These facts seem to indicate that the Mississippi Valley Basin was the metropolis for this great crinoidal fauna.

During this period the Cincinnati arch was above sea level, and from this island clastic sediments were being deposited off its western and southwestern shore, which constitute, in part at least, the Knobstone formations of Indiana and Kentucky, although the basal portion of the Knobstone is undoubtedly of Kinderhook age. The faunas associated with these clastic sediments are usually more meager than in the calcareous sediments of the clear seas farther west, and are somewhat different in character; however, they possess much in common as is evidenced by the wonderfully prolific crinoid fauna of the Crawfordsville beds in Indiana.

The later phases of the Osage sedimentation became more clastic, especially toward the north, doubtless because of the elevation of the land to the north, and in the Keokuk formation numerous shaly layers occur, intercalated between limestone beds. The shales become more and more dominant until, in the Warsaw formation, shales constitute the major portion of the sedimentation. In the southern portion of the Mississippian Basin this change in sedimentation was less or even not at all effective, since the Warsaw, as a distinct shale

horizon, is scarcely or not at all recognizable beyond a short distance south of St. Louis. The fauna of these shaly Warsaw beds is more or less closely allied to that of the subjacent formations, but it contains numerous species which are quite distinct and some which are either identical with, or related to, members of the superjacent faunas.

Subsequent to the Warsaw sedimentation the land to the north of the Mississippi Valley Basin was elevated. The Salem limestone which lies immediately above the Warsaw has a thickness of only 8 or 10 feet at Warsaw, Ill.,¹ where the formation consists of an impure, arenaceous limestone. To the south it increases in thickness to a maximum of about 100 feet, and is for the most part a very pure limestone, although magnesian layers are not unusual. The formation extends eastward beneath the younger formations, and is again exposed in western Indiana, off the western shore of the old Cincinnati island. A notable feature of the formation is the presence in it, throughout its entire geographical extent, of more or less extensive oölitic beds.

The fauna of the Salem limestone, commonly known as the Spergen Hill fauna, contains many diminutive forms, one of the most common species being *Cliothyris hirsuta*, which was present in a Kinderhook oölite at Burlington, Ia. Several small forms of *Conocardium* are also common in the fauna, one of the species, *C. meekana*, being somewhat closely allied to *C. pulchellum* from the same Kinderhook oölite. A comparison of the fauna with the Mississippian faunas of other parts of North America indicates a close relationship with certain faunas far to the northwest in Montana and Idaho. Meek² has recorded a fauna from a limestone in Idaho in which nearly one-half of the forms are identical with Spergen Hill species, and in the Yakinikak limestone³ in northwestern Montana a similar fauna also occurs. These limestones in Montana and Idaho are doubtless to be associated with the Madison limestone of the Yellowstone National Park, in which occurs a fauna having relationships with the Kinderhook of the Mississippi Valley, and especially with that of the Kinderhook oölite bed at Burlington, Ia., a relationship which may account for the partial recurrence in

¹ Ill. State Geol. Surv., Bull. No. 8, p. 90.

² Am. Jour. Sci. (3), V, 383.

³ Bull. Geol. Soc. Am., XIII, 324.

the Salem limestone of a fauna which has some features in common with this earlier fauna of a similar earlier oölitic bed.

Superjacent to the Salem is the St. Louis limestone which attains a maximum thickness of 250 feet, but in the northern portion of the Mississippian province it is reduced in thickness and lies unconformably upon the Salem, this unconformity being well shown near Warsaw, Ill. This unconformity indicates that the Mississippian sea retreated to the south during late Salem time, and readvanced in early St. Louis time. The retreat did not reach as far as Alton, Ill., however, as near that city the succession is perfectly conformable. The lowermost bed of the St. Louis in the north is a conspicuous limestone breccia which may be a northward continuation of a brecciated horizon near the middle of the formation in the region about St. Louis and Alton, but in following the formation to the south this brecciated horizon becomes less conspicuous and disappears. The fauna of the St. Louis is on the whole a meager one, and is quite different from that of the Salem. In some respects it suggests a recurrence of the Osage fauna, although the species are essentially all different, and some forms, of which the coral *Lithostrotion canadense* is perhaps the most notable, are distinctly new elements in the fauna.

The St. Louis is followed conformably by the Ste. Genevieve limestone. This formation differs from the St. Louis and resembles the Salem in the presence of oölitic beds, and with the recurrence of these conditions favorable for the formation of oölitic limestone, there is also a recurrence of the Salem fauna. Many species of the Ste. Genevieve are identical with those in the Salem, although the fauna contains species also which are characteristic to it. Among the latter a conspicuous one near Alton and in Monroe County, Ill., is *Pugnax ottumwa*, this species being present to the exclusion of all others in some localities. The abundance of the same species in the Pella beds of Iowa, the highest division of the so-called St. Louis of that state, suggests the correlation of these beds with the Ste. Genevieve rather than with any part of the St. Louis proper. This occurrence in Iowa is in accord with conditions elsewhere which indicate that the Ste. Genevieve was a time of great expansion of the Mississippian sea in all directions. It was at this time only, during the entire Mississippian period, that limestone conditions obtained in the northern part of the

more or less inclosed Appalachian Basin east of the Cincinnati island, where the Maxville limestone represents the Ste. Genevieve formation of the Mississippi Valley. To the southwest, in northern Arkansas, the Spring Creek limestone, a formation which, with the Batesville sandstone, is essentially contemporaneous with the Ste. Genevieve, and probably unconformable upon the subjacent Osage beds, carries a most remarkable fauna with peculiar immigrant forms from the far southwest,¹ a faunal character which indicates that the Mississippian sea reached so far in that direction as to communicate with the Western Continental Province, where these peculiar forms had existed, some of them having persisted from Devonian time.

Subsequent to the great extension of the sea during Ste. Genevieve time the northern portion of the Mississippi Valley Basin became dry land, and so remained until it was reoccupied by the sea in Pennsylvanian time, with only a partial readvance in early Chester time. In the extreme southern portion of Illinois and in Kentucky, Ulrich² has recognized three members in the Ste. Genevieve formation, the Fredonia, the Rosiclare, and the Ohara, but in all the region north of Chester, Ill., the upper portion is wanting and the superjacent Cypress sandstone rests unconformably upon the lower beds of the Ste. Genevieve. The higher beds of the Ste. Genevieve in the extreme southern Illinois, especially the Ohara beds of Ulrich, bear a fauna which has much in common with the faunas of the Chester above the Cypress sandstone, but even here there is possibly an unconformity between these beds and the Cypress.

The Cypress sandstone initiates the Chester, the closing epoch of the Mississippian in the typical portion of the Mississippi Valley Basin, during which period the conditions of sedimentation were continually shifting, there being interbedded limestone, shale, and sandstone formations, the limestone and shale predominating below, above the initial Cypress sandstone, and the sandstones being more conspicuous above. No remnant of these beds is preserved, so far as known, north of a point some miles south of St. Louis, although it is possible that the Chester sea extended further north than this. It is quite certain, however, that this sea never had the great extent to the

¹ Williams, *Am. Jour. Sci.* (3), XLIX, 94-101.

² *Professional Paper*, U. S. G. S., No. 36, p. 38.

north which had obtained during some of the earlier Mississippian periods.

The faunas of the Chester beds have a certain individuality of their own, although the successive limestone beds, in which the fossils mostly occur, have not yet been faunally differentiated with any great success. A conspicuous feature of the fauna is the presence of numerous blastoids of the genus *Pentremites*, and bryozoans, especially of the genus *Archimedes*. Among the brachiopods, especially, there is some recurrence of species identical with, or closely allied to, forms in the Salem and Ste. Genevieve limestones, but this characteristic is not limited alone to the brachiopods.

In the typical portion of the Mississippi Valley Basin the Mississippian period closes with the withdrawal of the Chester sea. Farther to the southwest, in Arkansas, however, toward the more open sea, it has been suggested by Ulrich¹ that similar faunas persisted into beds which are really of Pennsylvanian age, under which interpretation the line between the Mississippian and the Pennsylvanian, in that region, would be somewhat arbitrarily drawn. It is not improbable that the Arkansas beds are younger than any in the Mississippi Valley, yet that fact should not necessarily be considered as sufficient basis for referring them to the Pennsylvanian. The time boundary between the two periods should be marked by the time of maximum withdrawal of the sea or the subsequent readvance during which new sets of conditions were introduced.

MISSISSIPPIAN FAUNAS OF THE APPALACHIAN BASIN²

During Mississippian time the Cincinnati arch constituted a barrier between the central Mississippian sea and the Appalachian basin, a gulf which lay between this island and Appalachia. Into this basin clastic sediments were being carried from the east, north, and west, so that the pure limestones of the Mississippi Valley are absent, and the faunas are neither so prolific nor so well differentiated. In this basin the Mississippian formations are included within the Pocono and Mauch Chunk formations of Leslie. The most definite point of faunal contact between this basin and the Mississippi Valley Basin is found in

¹ *Professional Paper*, U. S. G. S., No. 24, p. 109.

² For a detailed description of the stratigraphy and correlation of the Mississippian of the Appalachian Basin, see Stevenson, *Bull. Geol. Soc. Am.* XIV, 15-96.

the Maxville limestone, whose fauna is to be correlated essentially with the Ste. Genevieve of southern Illinois and Missouri. It has been shown by Stevenson¹ that only the upper portion of the Pocono is of Mississippian age, and that this part is stratigraphically continuous with the Waverly group of Ohio. The basal member of the Waverly group, in the more general application of that term, is the Bedford shale in which occurs a fauna with Hamilton affinities.² As has already been pointed out, this fauna is believed to be associated with the incursion of the Hamilton-like forms which constitute one element in the southern Kinderhook faunas. The composition of the succeeding Waverly faunas has been more carefully studied by Herrick³ than by anyone else, and they exhibit throughout more or less affinity with the Kinderhook faunas of the Mississippi Valley Basin. Numerous members of the fauna suggest a Devonian derivation sometimes from Hamilton and sometimes from Chemung progenitors, as if they were to some extent a mingling of the two Kinderhook faunas of the Mississippi Valley. These Waverly faunas are, however, in no wise to be considered as contemporaneous with the Kinderhook alone of the Mississippi Valley, but they must also represent the Osage. In the Appalachian Basin, with its continuity of clastic sedimentation, environmental conditions similar to those of the Kinderhook persisted through Osage time, consequently there is no sharp differentiation of the faunas as there was in the Mississippi Valley where the period of clastic sedimentation was displaced by the clear seas in which nothing but calcareous sediments were deposited. For this reason the typical Burlington and Keokuk faunas do not occur in the Appalachian Basin, but an occasional member of these faunas found its way into the basin and such forms left records which are of value in the correlation of the faunas.

Outside of Ohio little or no detailed faunal study of these beds has been made, but Stevenson⁴ has pointed out the stratigraphic correlation of the beds throughout the Appalachian Basin from Pennsylvania to Alabama.

¹ *Loc. cit.*

² Herrick, *Geol. Surv. Ohio*, VII, 507.

³ A summary of Herrick's work is to be found in *Geol. Surv. Ohio*, VII, 495-515.

⁴ *Loc. cit.*

In the Mauch Chunk series of earlier authors, Stevenson¹ recognizes three members, a lower the Tuscumbia, a middle the Maxville, and an upper the Shenango. Toward the close of Pocono time there was a marked contraction of the sea in the Appalachian Basin, just as was the case at a corresponding time in the Mississippi Valley Basin. This contraction was of such proportions that the Tuscumbia beds were not deposited in Ohio in the area occupied by the earlier Waverly, except at the Kentucky border, but, as in the west, there was a readvance of the sea until it had reached its maximum extent in the deposition of the Maxville limestone which is to be correlated essentially with the Ste. Genevieve limestone of the Mississippi Valley. Such a correlation would make the Tuscumbia essentially contemporaneous with the St. Louis limestone of the Mississippi Valley, a correlation which is sustained by the paleontologic evidence. The Shenango is said to contain fossils characteristic of the Chester of the Mississippi Valley,² and may be correlated with that formation.

MISSISSIPPIAN FAUNAS OF THE ROCKY MOUNTAIN BASIN

In Montana and elsewhere in the northern Rocky Mountain region, limestones of Mississippian age are widely distributed, although but little data in regard to the faunas have been published. The most notable contribution to our knowledge of these faunas is that of Girty on the Carboniferous fossils of the Yellowstone National Park.³ The faunas here described are distributed through more than 1,600 feet of strata of the Madison limestone, but they do not show any such differentiation as is recognized in the Mississippi Valley. One general fauna persists with but minor changes throughout the entire series and this fauna shows many affinities with the southern Kinderhook faunas of the Mississippi Valley, as well as with the fauna of the Salem limestone. Faunas allied to that of the Salem have also been detected elsewhere in the region, as the Idaho fauna noted by Meek and the fauna of the Yakinikak limestone already mentioned. These relations suggest that in this northwestern region a long-lived fauna, having more or less close relationships with the Salem fauna, was contemporaneous with the larger part of the entire Mississippian series of the

¹ *Op. cit.*, p. 85.

² Stevenson, *op. cit.*, p. 85.

³ *Monograph*, U. S. G. S., XXXII, Pt. 2, pp. 479-599.

Mississippi Valley. At intervals this fauna made incursions into the Mississippi Valley Basin, as is evidenced by its representatives in the Kinderhook oölite at Burlington, Ia., in the Salem limestone, again in the Ste. Genevieve, and to some extent also in the Chester. That this is not a complete interpretation, however, is shown in the occurrence of a group of crinoids described by Miller and Gurley from near Bozeman, Mont.,¹ which strongly suggests the crinoid fauna of the lower Osage horizons of the Mississippi Valley. It is not improbable that when our knowledge of these faunas in the northwest is expanded, we may be able to recognize elements related to most or all of the faunal divisions of the Mississippi Valley. The evidence at present available suggests that this region occupied a distant part of the same sea which was present farther to the southeast, and that there was more or less unobstructed means of faunal communication between the two regions.

From the Lake Valley region in New Mexico, there has been described an early Mississippian fauna² which is a close ally of the fauna of the Fern Glen formation at the summit of the Kinderhook in the Mississippi River section south of St. Louis. This occurrence indicates that the Mississippian sea had transgressed at least as far to the southwest as New Mexico by the close of Kinderhook time, and that means for faunal communication was unobstructed in that direction.

The Mississippian faunas from Colorado have been described by Girty³ who has reported on materials collected in nine separate regions from the Ouray, Leadville, and Millsap limestones. All of these faunas are separated into two groups by that author, both of which are considered to be of essentially the same age, early Mississippian, probably Kinderhook or early Osage. The composition of the fauna is strikingly like that of the Madison limestone of the Yellowstone National Park, its relationships being especially with the Chouteau of the Mississippi Valley Basin, but the presence of such forms as *Eumetria marcyi*?, *Straparollus cf. spergenensis*, *Fenestella serratula*?,

¹ *Bulletin*, Ill. St. Mus. Nat. Hist., No. 10. "*Poteriocrinus bozemanensis* P. douglassi, and *Platycrinus douglassi*;" *ibid.*, No. 12, "*Batocrinus douglassi*, *Rhodocrinus douglassi*, *R. bozemanensis*, *R. bridgerensis*, *Platycrinus bozemanensis*, *P. bridgerensis*, *Dichocrinus bozemanensis*."

² Miller, *Jour. Cin. Soc. Nat. Hist.*, IV, 306-15; also Springer, *Am. Jour. Sci.* (3), XXVII, 97-103.

³ *Professional Paper*, U. S. G. S., No. 16.

etc., suggest also a relationship with the Salem limestone fauna of the Mississippi Valley. The conditions are therefore similar to those in the Madison limestone of the North, and the interpretation of the faunal relations in that region can doubtless be extended to the more southern area.

MISSISSIPPIAN FAUNAS OF THE WESTERN CONTINENTAL PROVINCE

For a knowledge of the Mississippian faunas of the Great Basin region we are especially indebted to Walcott, who has described them from the Eureka district of Nevada.¹ The faunas occur at various horizons through a series of "Lower Carboniferous" limestones 3,800 feet in thickness, and are most remarkable from the fact that there is a general mingling of forms which, if found in the Mississippi Valley, would be considered as characteristic either of the Devonian, the Mississippian, or the Pennsylvanian. There is, however, a notable absence of the more conspicuous elements of the Mississippian faunas of the Mississippi Valley, such as the crinoids of the Osage faunas, the large *Spirifers* of the *S. striatus* type, the *Archimedes* and *Pentremites* of the Chester faunas, etc. None of the specialized Mississippi Valley faunas can be recognized. This basin must have been isolated, during Mississippian time, both from the Mississippi Valley and from the Rocky Mountain basins. The one point of faunal contact between the Great Basin and the Mississippi Valley is found in the presence of several of the peculiar Great Basin forms in the fauna of the Spring Creek limestone of northern Arkansas, among which *Rhynchonella eurekaensis* and *Leiorhynchus quadricostatus* are perhaps the most notable. The age of the Spring Creek limestone is believed to be very close to that of the Ste. Genevieve limestone, at which time, perhaps, the Mississippian Sea had its greatest extension in the East. With this expansion of the sea there would seem to have been established a brief communication with the Great Basin region, of such a nature as to allow a group of these peculiar forms to migrate at least as far east as northern Arkansas. It is apparently impossible to correlate this incursion in the Great Basin, however, perhaps because of our imperfect knowledge, because the most notable of the immigrant species, *R. eurekaensis*, has a long range in the Great Basin beds.

¹ *Paleontology of the Eureka District*, Monog., U. S. G. S., Vol. VIII.

DISCUSSION

Professor Calvin

The paper presents very fairly and fully the taxonomic relations of the Devonian and the Mississippian so far as Iowa is concerned. I should be disposed to question the propriety of correlating the Sweetland Creek shales of Muscatine County with any part of the Kinderhook. It is true that in Missouri beds which have been referred to the Kinderhook furnish *Ptyctodus* and some other Devonian types; but at Burlington the Kinderhook shales carry a fauna that, in practically all its aspects, is Carboniferous. On the other hand, the fauna of the Sweetland Creek shales is characteristically Devonian. Leaving out *Ptyctodus*, which may belong to either of the two formations, all the other life forms will be found to be distinctively Devonian. The Sweetland Creek beds furnish two species of *Synthetodus*, a form very common in the State Quarry limestone. Now the State Quarry limestone is in large part made up of imperfectly comminuted shells of that most intensely non-Carboniferous of all the Devonian types, *Atrypa reticularis*, with occasional shells of another almost equally intensely Devonian form, *Gypidula comis*. Fossils are rather rare in the Sweetland Creek beds, but all that have been noted are such as to exclude this formation from any close relation to the Kinderhook.